



Using satellite imagery to assess the influence of urban development on the impacts of extreme rainfall

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Abstract

We investigate the applicability of medium resolution Landsat satellite imagery for mapping temporal changes in urban land cover for direct use in urban flood models. The overarching aim is to provide accurate and cost- and resource-efficient quantification of temporal changes in risk towards the impacts of pluvial flooding. Initial results show that satellite imagery may have considerable potential in this respect.

INTRODUCTION

Changes in the quantity and location of impermeable surfaces (IS) have important implications for the hydrological response during high intensity rainfall events. Knowledge hereof is key input in relation to urban flood modelling (Butler, 2011). However, as urban land-use is characterised by a large degree of heterogeneity it is often problematic to categorise and map urban structure and development accurately at the desired scale (Dams et al., 2013).

Satellite imagery and remote sensing techniques offer a complete spatial and temporal coverage of urban land cover changes during the past 30-40 years. Medium resolution imagery provides the necessary spatial resolution and temporal coverage for analysis of small scale urban land cover changes, including variations in IS. Utilising satellite imagery in pluvial flood modelling allows for systematic investigations of the relationship between urban land cover changes and changes in risk towards the occurrence and impacts of urban flooding (Weng, 2012).

In this study a data driven modelling approach, cf. Figure 1, is used to study the applicability of medium resolution

Landsat satellite imagery for examining changes in the hydrological response and the potential impacts of pluvial flooding due to recent urban development. The city of Odense, Denmark, serves a trial case for the proposed methodology.

METHODOLOGY

Figure 1 shows a proposed methodological framework to serve as systematic basis for investigating and quantifying changes in flood risk for urban areas. The framework is organised around three major analytical and modelling components feeding into the impact assessment: urban remote sensing analysis (changes in IS and land use), 1d/2d hydrological modelling (e.g. encompassing overland and drainage system flows modified with and without climate change projections) and spatial impact modelling (including direct and indirect economic costs, the effect of installing suitable adaptation measures, etc.)

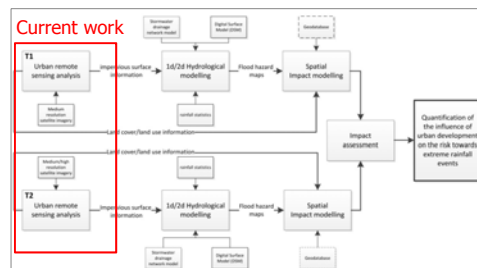


Figure 1. Overview of methodological framework

The three components are interconnected as illustrated in the figure, i.e. the output of one element feeds into the next element, starting from left to right. T1 and T2 refer to different points in time during which the change in risk is explored. Here we only examine the first element in the chain.

IMPERVIOUS SURFACE MAPPING

The impervious surface analysis is based on the notion of a near linear relationship between vegetation cover and impervious surfaces in urban environments (Bauer et al, 2007).

Most remote sensing estimates of vegetation distribution are based on some measure of 'greenness', utilising the difference in reflectance between vegetated and non-vegetated areas. Green vegetation has been found to reflect a much larger proportion of the incoming radiation in the near infrared wavelengths than in the red wavelengths (Jensen, 2007). This difference in reflectivity/absorption forms the basis for monitoring vegetation cover through the use of satellite imagery. For the current analysis the Normalized Difference Vegetation Index (NDVI) has been applied as a proxy for vegetation cover.

$$NDVI = \frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + \rho_{red}}$$

In order to be able to estimate historical changes in impervious land cover using Landsat imagery a regression model relating Landsat 8 NDVI values and % impervious land cover from high resolution aerial photography has been developed and tested (see Figures 2-5).

DATA

Vegetation cover: 30 meter resolution Landsat 8 NDVI Maximum Value Composite (MVC) for May-July 2013.

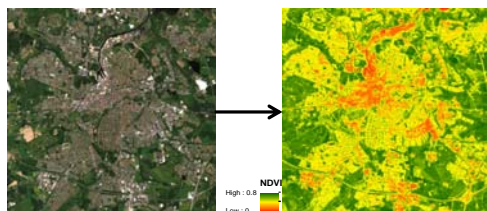


Figure 2. (left) Landsat true colour image June 2013, (right) MVC NDVI May-July 2013

Impervious surface cover: Supervised classification of 0.5 m aerial photography, aggregated to 30 m resolution

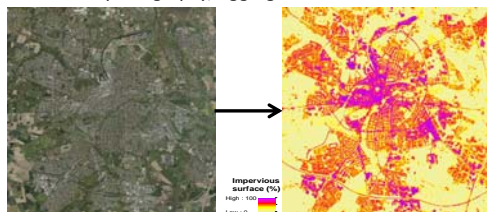


Figure 3. (left) Aerial photography (right) Impervious surface cover (%)

RESULTS

An ordinary least squares (OLS) regression analysis relating the NDVI and impervious surface cover for a trial case - the city of Odense, Denmark - is presented in figure 4 and 5. From the figures a clear linear relation can be observed, however with some systematic deviations. The most pronounced errors include areas with bare soil and areas where vegetation (e.g. treetops) covers impervious surfaces.

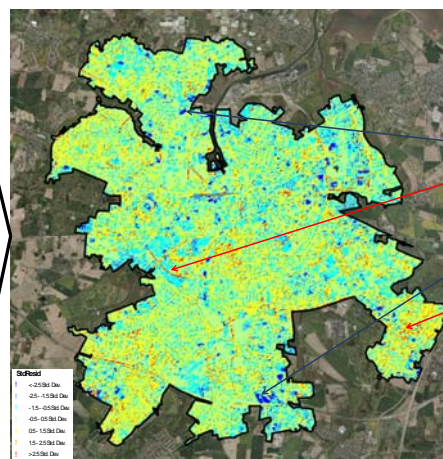


Figure 4. Std. Res. OLS regression, Impervious surface and NDVI, City of Odense, Denmark

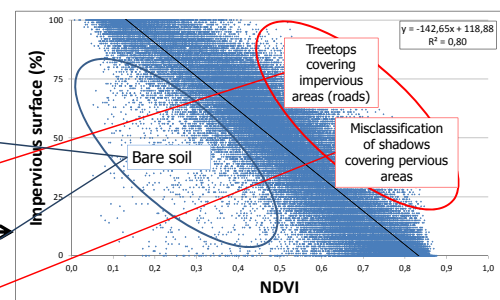


Figure 5. OLS regression impervious surface and NDVI, City of Odense, Denmark

CONCLUSION

Initial results suggests that medium resolution satellite imagery and remote sensing methods may provide improved estimates of impervious surface cover for direct use in urban hydrological modelling.

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